A Business Case for the Deployment of a 4G Wireless Heterogeneous Network in Spain

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Introduction

The success of wireless communications, the creation of more complete and smaller devices, and the emergence of the Internet have transformed communications in residential and business environments. The emergence of wireless packet-switched networks such as Universal Mobile Telecommunications System (UMTS), wireless local-area networks (WLANs), and worldwide interoperability for microwave access (WiMAX) allows the introduction of innovative services and opens up a new range of revenues. It is considered that fourth generation (4G) wireless networks could be heterogeneous with different access technologies. The convergence of services such as voice, video, and data has important consequences. The provisioning of voice, data, and video services over one network, or the integration of networks onto one network, is becoming a reality. Moreover, the introduction of IMS architecture in the core network of packet-switched networks permits rapid deployment of new services.

Building a business case for the introduction of a new technology implies a great number of hypotheses and assumptions such as the penetration rate, capital expenditures (CAPEX), operational expenditures (OPEX), and market share rate. It is impossible to get an exact forecast of its performance. Nevertheless, the utility of a business case is to offer a reasonable estimate that allows the construction of scenarios for the future. On the other hand, a business case should be as realistic as possible in order to be useful and reflect all the variables of interest of the market as well as their evolution and expected behavior.

One of the milestones in this area is the work done by Forge, Blackman, and Bohlin, who designed a business model and a business case for a 4G "linear network": a fictitious country named "Eurolandia," which represents an average country in western Europe, was created according to density population and demand of services [1, 2]. Another report describes the requirements and new technical and economical challenges that a 4G network will face in its deployment, including bandwidth capacity, interoperability, seamless connectivity between wireless and wired technologies, quality of service (QoS), security, and network management [3]. There is another business case for a citywide wireless fidelity (Wi-Fi)/WiMAX deployment that offers the same broadband services as digital subscriber line (DSL). The architecture that this model proposes is a Wi-Fi network built around a complete city with a WiMAX network as backhaul. With this solution a profitable business case and a cost-effective service model affordable to all types of users was determined [4]. Recent work done by the European ITS ECOSYS project proposes a few business models for telecom operators in different situations. All inputs to the model are based on real issues from Nordic countries such as Sweden and Norway and large countries such as France and Germany. These inputs include coverage area, type of users, expected traffic, and population density. The results delivered are different CAPEX, OPEX, and revenues for each operator in each scenario [5].

In this paper, a business case for a 4G "concurrent network," similar to a heterogeneous network, is presented. To the authors' knowledge, in the literature there are no business cases done for these kinds of networks in Spain. The architecture consists of a combination of air interfaces (general packet radio service [GPRS]/UMTS, WLANs, and WiMAX) and an Internet protocol multimedia subsystem (IMS) as a core network. The main reason for this architecture is the reusability of components that the IMS architecture provides in the core network and the velocity at which new services can be offered. The input to the simulation is based on statistics from Spain. Two areas were considered in the study: an urban area with high population density, and a rural area with low population density. The insight acquired from this model could be extrapolated to other countries with similar characteristics in western Europe.

The paper is organized as follows: section 2 describes the general assumptions used at the moment of building the business case; section 3 presents the business case; section 4 describes the results; and section 5 concludes the paper.

General Assumptions

To obtain our results, we considered a number of assumptions that are described below. It has to be mentioned that the network operator described is supposed to be a Global System for Mobile Communications (GSM) and a UMTS licensee.

Geographical Coverage

One of the most important factors for a business case is the coverage area of the network due to its influence on the deployment cost. The geographical areas that have been considered are a city with high population density and a region with low population density. These areas are described below.

Urban Area

The city of Barcelona, which is in the autonomous community of Catalonia, inside the province of Barcelona, was chosen due to the high population density and the high demand of services. Demographic indicators are presented in *Table 1* [6].

Rural Area

The region of La Vera, which is in the autonomous community of Extremadura, inside the province of Caceres, was chosen due to its low population density and its relatively low service demand compared with the average regions. *Table 2* shows the surface, population, and population density of each one of the municipalities that constitute the region of La Vera [6, 7]. It should be noted that the sum of the surfaces of all municipalities is not equal to the total surface of the region; for this study, the deployment of the network took only into account the territory of the municipalities and

TABLE 1

Total Population and Territorial Characteristics of Barcelona.

City	Surface (km^2)	Population	Density (pop/km^2)
Barcelona	100.69	1,605,602	15,596

TABLE 2

Total Population and Territorial Characteristics of La Vera.

Municipality	Surface (km^2)	Population	Density ($pop./km^2$)
Madrigal de La Vera	43	1,757	40.86
Valverde de La Vera	47	650	13.83
Viandar de La Vera	28	303	10.82
Talaveruela de La Vera	21	465	22.14
Losar de La Vera	82	3,231	39.4
Robledillo de La Vera	13	344	26.46
Jarandilla de La Vera	62	3,298	53.19
Guijo de Santa Bárbara	35	508	14.51
Aldeanueva de La Vera	38	2,439	64.18
Cuacos de Yuste	53	976	18.42
Jaraíz de La Vera	66	7,530	114.09
Garganta La Olla	48	1,173	24.44
Pasarón de La Vera	39	725	18.59
Arroyomolinos de La Vera	23	566	24.61
Gargüera	52	201	3.87
Torremenga	12	616	51.33
Tejeda de Tiétar	53	987	18.62
Villanueva de La Vera	130	2,134	16.42
Collado	45	250	5.56
Total	890	28,153	31.63

an extra 15 percent of the total surface that represents the paths and highways that interconnect each municipality.

Figure 1 shows the location of all the municipalities in the region of La Vera.

Figure 2 illustrates the location of the zones taken into account for this study. The autonomous communities of Catalonia and Extremadura are presented, as well as the provinces of Barcelona and Caceres, the city of Barcelona, and the region of La Vera.

Architecture of the Network

The network architecture selected for this study consists of a heterogeneous network, in which access is provided by Wi-Fi, UMTS, and WiMAX subnetworks. These interfaces will

FIGURE 1

Map of the Region of La Vera [7].

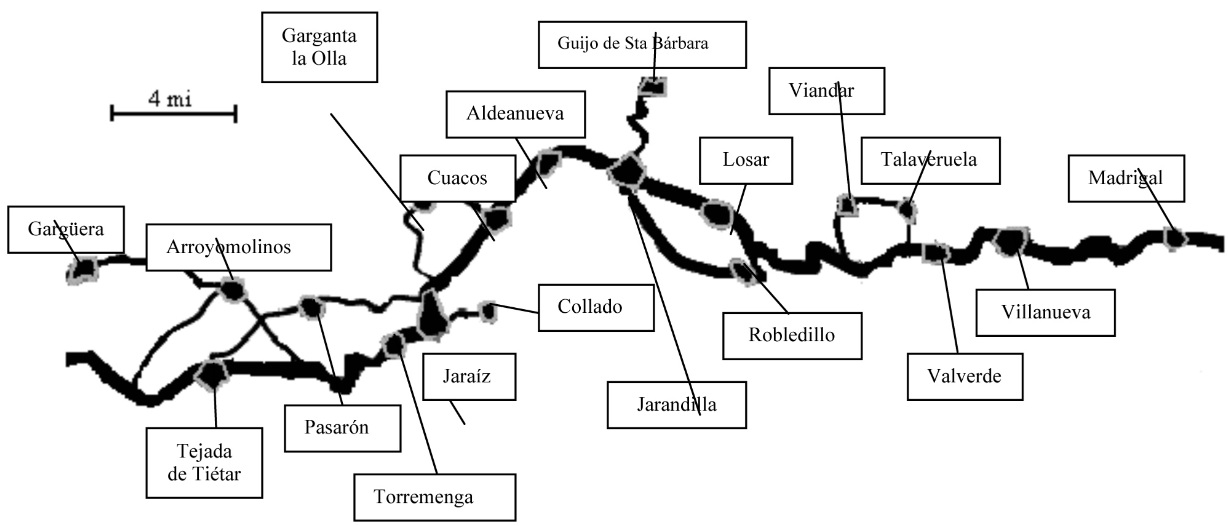
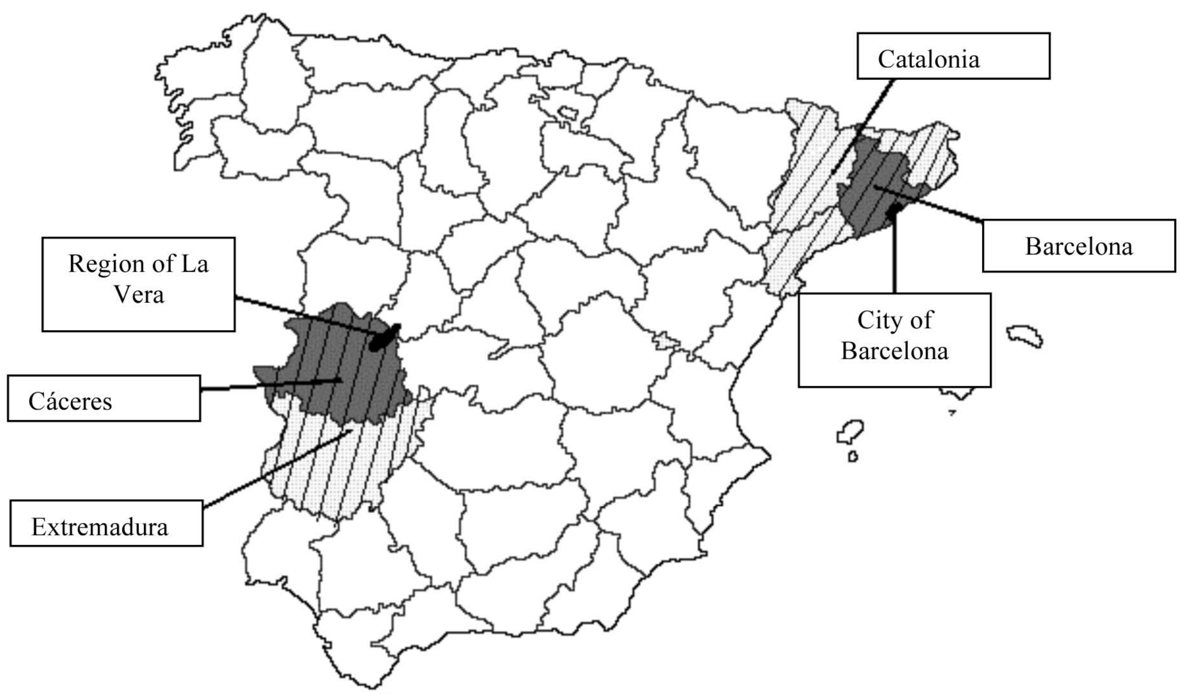


FIGURE 2

Location of the Urban and Rural Areas in Spain.



cover the territory according to the benefits that each technology provides and the current deployment done by the operator. In the core network the IMS architecture will be used for the easy integration of services provided in the different subnetworks. The core network will have interconnection to the Internet and to PLMN and PSTN networks. *Figure 3* illustrates the network architecture used in this study.

Handset Types
To offer a broader network coverage, it is assumed that end users' devices will be able to connect to different wireless interfaces, which means that subscribers will not lose their profile when they change from one type of network to another. The handsets that may be available in this network are as follows:

- **Only cellular capabilities**—This type of mobile will be able to connect to a GSM/GPRS network if there is poor UMTS coverage or none.
- **PDAs and laptops**—These devices and computers will operate with UMTS/Wi-Fi connections or with UMTS/WiMAX networks.

Business Model
In one of the deliverables generated by the EU ITS ECOSYS project, it was stated that a "business model consist[s] of service and information flows, including a description of various business players, their roles and relationships, their relative position within a value network and descriptions of their costs structure and source of revenue" [8]. In our study, two main actors were taken into account: the network operator (NO), which acts as service operator (SO), and the content producer/provider. *Figure 4* shows the main cash flows between actors and the roles that each actor plays in the business model considered in this study; this is based on a business model developed by the ECOSYS project. Each ellipse or circle means a different actor, and each rectangle represents a different role for the actor [8]. The NO is responsible for the correct provisioning of contents such as downloads of music, games and videos, and voice and data transfers to the subscriber. The content producer is the entity that creates or promotes the videos, games, and music that the NO sells the subscriber. The NO is responsible for the provisioning of the bandwidth that the SO offers to the subscriber.

Definition of the Business Case
Figure 5 describes the main logical flows that are assumed in order to obtain economic results for the business case. The chart flow is based on the research carried out for the ECOSYS project [5].

Inputs for the business case are the size of the territory, population, market share, penetration rate, average revenue per user (ARPU), timeframe for the study period, and equipment costs. Outputs for the business case are the net present value (NPV), internal rate of return (IRR), cumulative and annual cash flows, payback period, and profitability index (PI). The variables that were used to obtain the results are the number of subscribers, ARPU, and CAPEX and OPEX values.

The timeframe considered in the study is eight years, which is a reasonable life cycle for wireless technologies and should be enough time for the payback period. This timeframe starts in 2008 and ends in 2015. On the other hand, the discount rate will be 15 percent, which is based on approximated discounted factors taken from other studies [1, 5].

For this business case, the NPV was chosen as the key economic indicator. According to [9], the NPV represents the present value of net cash flows. The following formula defines the NPV:

$$NPV = -CF_0 + \sum_{i=1}^{n} \frac{CF_i}{(1+rate)^i}$$

FIGURE 3

Network Architecture Assumed for the Business Case.

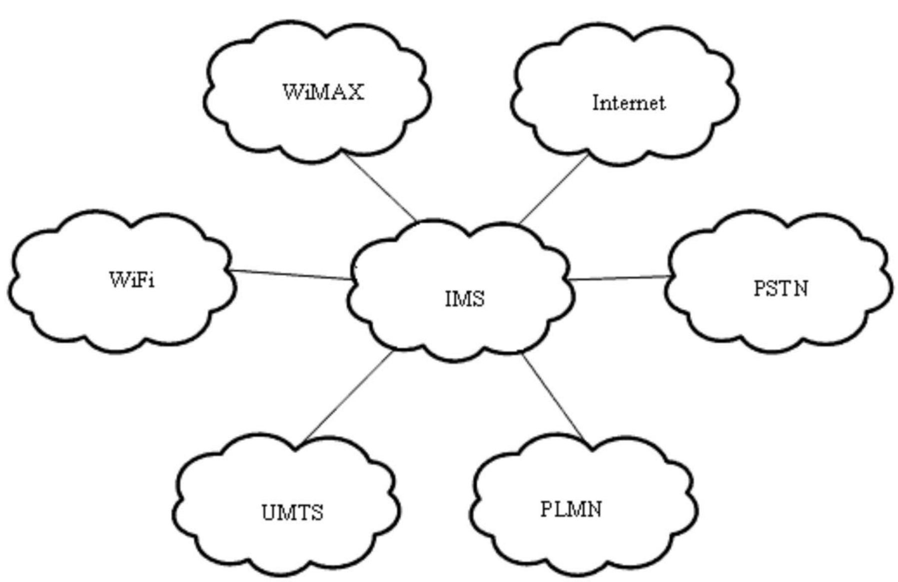


FIGURE 4

Main Cash Flows and Roles for the Model (Based on the EU ECOSYS Project [8]).

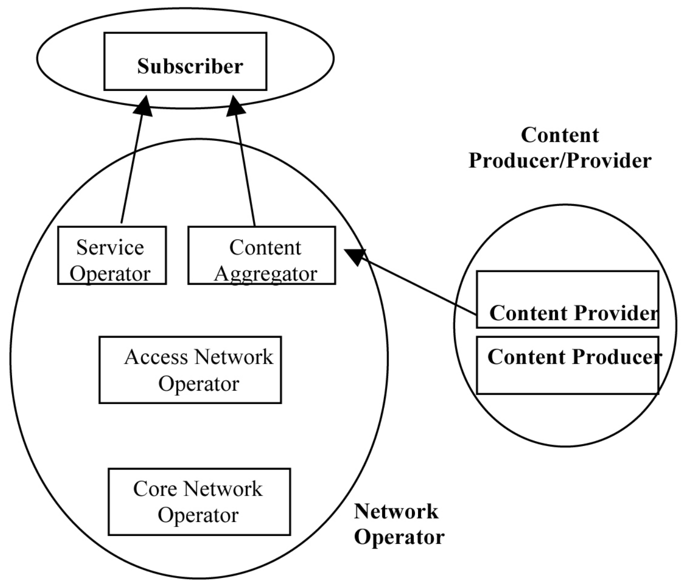
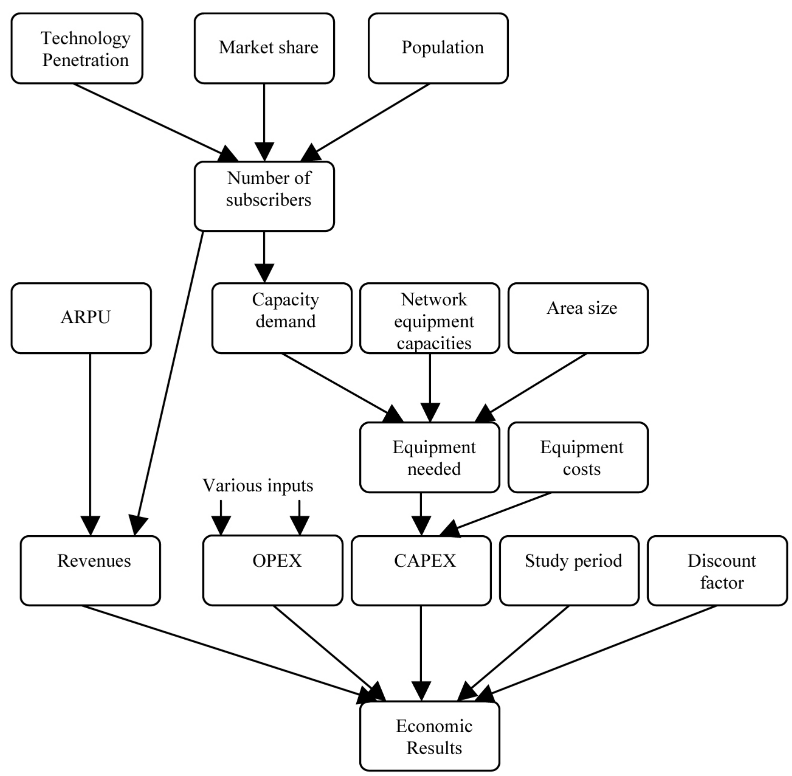


FIGURE 5

Model Revenues and Cost Flows (Based on the ECOSYS Project [5]).



where i is the time of the cash flow, n is the total time of the project, rate is the discount rate, CF_i is the net cash flow (the amount of cash) at time i, and CF_o is the capital outlay at the beginning of the investment time (t = 0).

In addition to the NPV, other economic indicators were used to provide more detailed information about the project. For example, the payback period, defined as the number of periods required for the sum of the project's expected cash flows to equal its initial cash outlay, is obtained when the cumulative cash flow passes zero, i.e., when the cumulative cash flow becomes positive [9].

The PI rule determines if a project is accepted or not: if the PI value is greater than 1, the project should be accepted; otherwise, it should be rejected. The PI is defined as the NPV divided by the initial investment. In the following formula, $presentValue(CF_1, CF_2, \ldots CF_n)$ represents the NPV of the project, whereas *InitialCashOutlay* represents CF_0 or the initial investment [9].

$$PI = \frac{presentValue(CF_1, CF_2, ...CF_n)}{InitialCashOutlay}$$

Business Case

Deployment Strategy

The air interfaces for the 4G wireless network were chosen by taking into account the population density and the demand of services in each area. The UMTS network will be completely deployed in two phases. In the first phase, due to the relatively low demand of UMTS network services, the purpose is to cover the territory as fast as possible, regardless of network capacity constraint. In the second phase, the objective is to provide an upgrade of the network capacity and core network. This is achieved by adding more transceivers at the base stations (BSs) and adding more elements at the core network. The first phase will be accomplished during the first year, whereas the second phase will be finished during the second and third year.

The Wi-Fi network will be deployed only in places with high population densities. The Wi-Fi network will be deployed during the first year. Finally, the WiMAX network will be deployed in places where the UMTS network has poor or no coverage, so that devices could improve the transmission speed; this network is assumed to cover 40 percent of the total area. The WiMAX network will be deployed during the first two years. *Figure 6* illustrates how the different wireless technologies will provide coverage to the area.

Market Forecast

Based on statistics from the National Regulatory Agency (NRA) of Spain, Comision del Mercado de las Telecomunicaciones (CMT) [10], the penetration of mobile telephony was 103.4 percent in the fourth quarter of 2006, and the market shares for the different operators was the following: Telefonica Moviles, Vodafone, and Orange had 46.2, 29.8, and 24 percent of the total market, respectively. In this study, the market share of Vodafone is used as starting point for the operator considered in the business case. According to the data published by Vodafone Spain [11], the coverage offered in 2007 with its GSM/GPRS network corresponds to 99.08 percent of the area in Spain, whereas its UMTS network had a smaller coverage.

According to statistics published by the CMT in Spain [12], in 2006 there were 46.2 million mobiles lines in Spain. *Figure 7* shows the evolution of mobile lines during the last seven years.

Based on these statistics, in this study a projection for the possible future number of subscribers was done by using three scenarios: the normal scenario, the optimistic scenario, and the pessimistic scenario. The normal scenario considers that the network operator continues with the same growth rate of the last seven years, as shown in *Figure 7*. The number of subscribers starts from the number of subscribers that Vodafone would have in 2008 according to the growth rate presented in *Figure 7*: 15,886,380 users. The optimistic scenario considers that the operator will have 5 percent more subscribers than in the normal scenario. In the pessimistic scenario the operator will have 5 percent fewer subscribers than in the normal scenario. *Figure 8* illustrates the number of subscribers that the operator will have for each scenario in Spain.

Tables 3 and *4* show the initial number of subscribers in the city of Barcelona and the region of La Vera for each scenario, respectively.

Traffic Generated by Users

According to the data published by the CMT in Spain [10], users can be classified according to two contract types: pre-

FIGURE 6

Network Coverage of WiMAX, Wi-Fi and UMTS Cells.

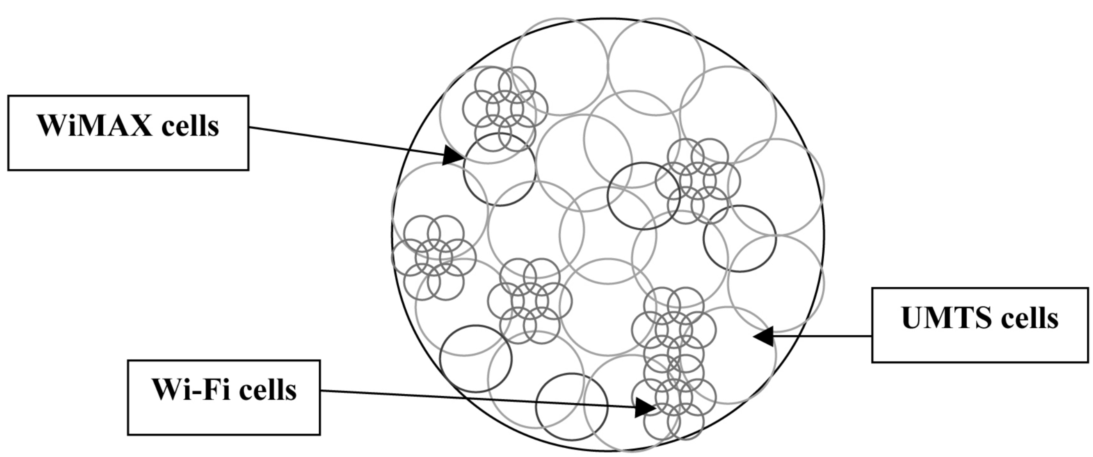


FIGURE 7

Mobile Lines Evolution in Spain.

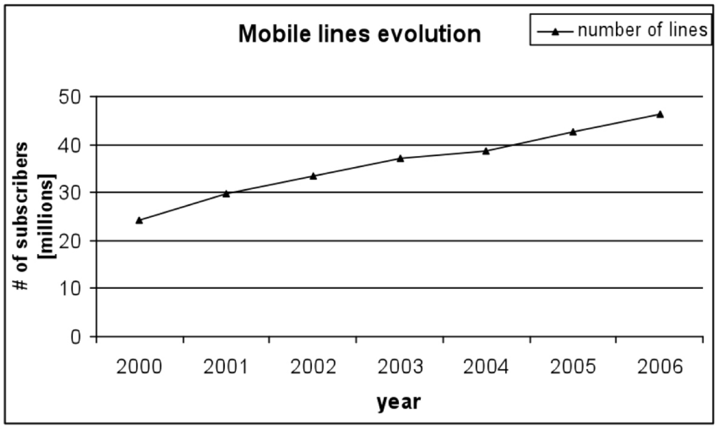


FIGURE 8

Market Forecast Scenarios for the 4G Operator.

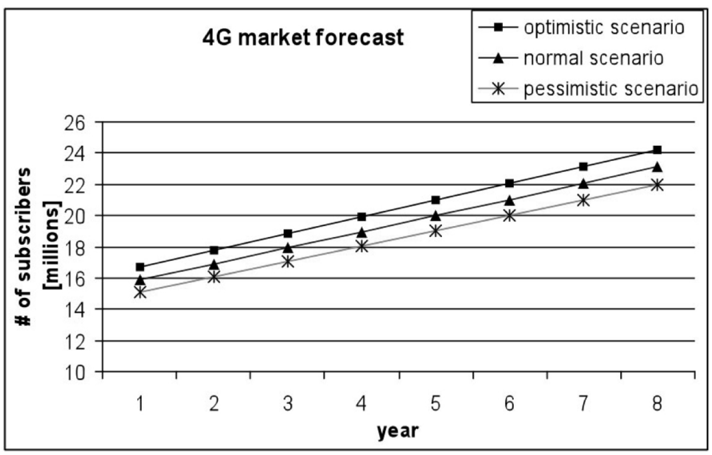


TABLE 3

Initial Number of Subscribers in the City of Barcelona.

Scenario	Subscribers
Optimistic Barcelona	593,626
Normal Barcelona	565,358
Pessimistic Barcelona	537,090

TABLE 4

Initial Number of Subscribers in the Region of La Vera.

Scenario	Subscribers
Optimistic La Vera	5,204
Normal La Vera	4,957
Pessimistic La Vera	4,709

paid users and postpaid users. Each type of subscriber has a different demand of services, depending on preferences and needs. *Table 5* shows an average expense in services for both types of users. Based on these results, in our business model we assume that an urban user can assign €25 per month to wireless cellular services, whereas a rural user can assign a third part of the expense of the urban user (€8.33) to wireless cellular services [5]. This result is obtained by dividing the total expense per trimester (€75.62) by three.

Scenarios Considered

This section describes the scenarios considered for the business case. In *Table 6* the scenarios for both areas are presented.

Network Dimensioning

This subsection describes the radius and the area that each BS covers depending on the technology used (UMTS, WiMAX, or Wi-Fi).

TABLE 5

Revenues Generated by Users.

Service	Prepaid (€)	Postpaid (€)	Total/trimester (€)
Voice	22.67	89.38	59.31
Subscription fee	0.02	3.27	1.8
Traffic	22.65	86.12	57.5
Data	7.72	15.86	12.19
SMS	6.24	11.96	9.39
GPRS services	1.25	3.26	2.35
WAP	0.23	0.64	0.45
Interconnection to other networks	0.78	6.87	4.12
Total	31.18	112.11	75.62

Based on the ECOSYS project [5], the BS coverage in the UMTS system is defined as shown in *Figure 9*. In this case the BS has three sectors.

Table 7 shows the radius and the BS coverage per UMTS BS.

For dimensioning the WLAN, the access point (AP) only transmits omnidirectionally and the coverage area assumed was a circle. *Table 8* shows the radius and coverage area in dense urban areas.

Finally, the WiMAX dimensioning is presented. The calculus is similar to that of the UMTS case. However, the results are different due to technology capabilities [5, 13]. *Table 9* shows the radius and coverage in the different types of areas considered.

Capital Expenditure (CAPEX)

The CAPEX considers the cost of the initial equipment and the cost of the license for the use of the spectrum necessary to deploy a new wireless technology. These costs are normally classified as assets of the company. For the purpose of this study, the CAPEX is divided into the following four parts: UMTS CAPEX, Wi-Fi CAPEX, WiMAX CAPEX, and IMS CAPEX.

UMTS CAPEX

This part consists of the costs for the deployment of a 3G BS, called Node B in the UMTS network. A BS requires a platform where the antenna is mounted; the platform gives security and support to the antenna. This construction has an approximated cost of €60,000 when there is no building. However, when there is a previous construction for an older wireless network, the cost is €30,000 due to the reuse of materials. The Node B has an approximated cost of €105,000 and €60,000 for urban and suburban/rural areas, respectively. The Node B contains transceivers of high or medium capacity depending on the zone: rural or urban. The transceivers are expected to have a basic capacity at the moment of network deployment. Later, when the network is completely deployed, the capacity is upgraded to support all the traffic demanded by users. This upgrade can cost €105,000 for urban zones and €60,000 for suburban and rural zones.

The radio network controller (RNC) has an approximated cost of €2,000,000; this device can support up to 400 Nodes B, 1,200 transceivers or 200 Mbps of capacity. In the initial phase of the deployment of the network it will only have a cost per BS of €5,000. In the second phase, which consists of the capacity upgrade, there is an extra cost for the RNC of

TABLE 6

Scenarios Considered for the Business Case.

	Scenario
1	Optimistic Barcelona
	Normal Barcelona
	Pessimistic Barcelona
2	Optimistic La Vera
	Normal La Vera
	Pessimistic La Vera

FIGURE 9

BS Coverage Definition (Based on the ECOSYS Project [5]).

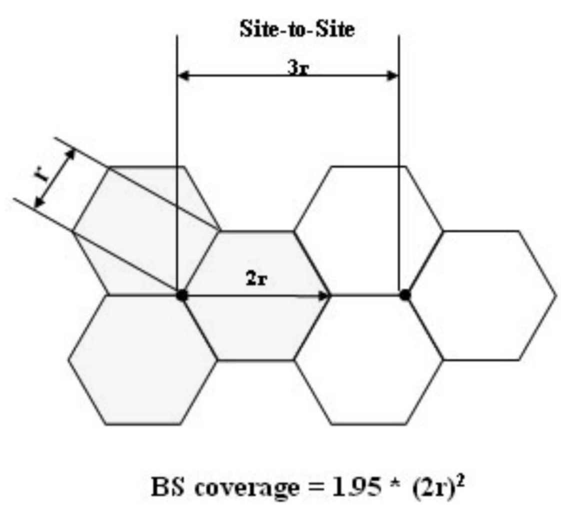


TABLE 7

Radius and Coverage per UMTS BS.

Area type	Radius (km)	Coverage (km^2)
Dense urban area	0.57	2.53
Urban area	0.89	6.18
Suburban area	2.11	34.73
Rural area	6.36	315.51

TABLE 8

WLAN Radius and Coverage in Dense Urban Areas.

Area type	Population density (pop./km^2)	Radius (km)	Area (km^2)
Dense urban area	6,000	0.20	0.13

TABLE 9

WiMAX Radius and Coverage per Area Types.

Area type	Radius (km)	Area (km^2)
Dense urban area	0.4	1.25
Urban area	0.6	2.81
Suburban area	1.1	9.44
Rural area	3	70.2

€75,000 and €35,000 for urban and suburban/rural zones, respectively. On the other hand, in the core network there are nodes such as the mobile switching center (MSC), the serving GPRS support node (SGSN), etc., that have a cost of around 30 percent of the total expenditure of the network. Finally, the replacement costs were considered. The replacement costs are the costs of replacing the components when after several years of usage the equipment stops working. This value is 8.7 percent of the total cost of the network [14].

Finally, according to [14–17], the license fee for the Spanish operators was on average €9.02/pop per year. The license is valid for 28 years and has been valid since 2002. In this model, the cost of the license fee per area was calculated as the total number of people in the area multiplied by the cost of the license per person. In *Table 10* the UMTS CAPEX values are summarized.

Wi-Fi CAPEX

The main CAPEX for a WLAN technology is the cost of the AP. An AP with the possibility of operating in the three standards (802.11a, 802.11b, and 802.11g) has a cost of approximately €1,000. The AP installation requires approximately 10 working hours, whereas the monthly payment of a worker is approximately €5,000. Therefore, there is an installation cost of €300 per AP. *Table 11* summarizes the CAPEX values for WLAN [13].

WiMAX CAPEX

The site has an approximate cost of €37,594.1 (50,000 USD). The WiMAX BS has a price of €37,594 (50,000 USD). The antenna has a four-sector configuration. The installation cost

TABLE 10

WiMAX Radius and Coverage per Area Types.

CAPEX Item	Cost (€)
Site build-out	60,000
Site upgrade	30,000
BS (urban)	105,000
BS (rural)	60,000
RNC	5,000
RNC upgrade (urban)	75,000
RNC upgrade (rural)	35,000
Core network	30%
Replacement	8.70%
License (urban)	14,479,353/year
License (rural)	253,884/year

TABLE 11

WLAN CAPEX Values.

CAPEX Item	Cost (€)
AP	1,000
Installation	300

of the antenna is €2,256 (3,000 USD). The costs for the core network, which contains routers, switches, network management system (NMS), etc., are €375,940 (500.000 USD) [18]. Finally, the license fee for WiMAX operators is Europe is €25,000 [19]. *Table 12* shows the WiMAX CAPEX values.

IMS CAPEX
The last part for the CAPEX is the cost of the acquisition of the IMS equipment, which has an average price of €500,000. This equipment can support up to 200,000 subscribers.

Operational Expenditures (OPEX)
In the present study the OPEX is divided into the following four groups: UMTS OPEX, Wi-Fi OPEX, WiMAX OPEX, and IMS OPEX.

UMTS OPEX
The site lease on which the BS is mounted has an approximate price of €10,000 per year in the urban areas and €3,000 per year in the suburban/rural areas. The cost for data transmission, also known as backhaul, is €5,000 per year. The cost of energy consumption, which is the electrical energy needed for the BSs, routers, switches, and other equipment, is approximately 3 percent of the total cost of the equipment. Therefore, it has a cost of €5,100 per year. Operation and maintenance costs, which are the costs generated by the personnel that is dedicated to maintaining and operating the equipment used in the network, are approximately 5 percent of the total cost of the equipment. Therefore, there is an expenditure of €8,500 per year [20]. *Table 13* summarizes the 3G UMTS OPEX values.

Wi-Fi OPEX
The site lease price of the APs is €90 per year. The maintenance costs of the APs was calculated taking into account that a employee can manage around 500 APs per month and the salary of the employee is €5,000 monthly. Therefore the annual cost for maintenance is €120 per annum [13, 20]. Finally, the cost to connect the APs to the core network is free due to the fact that the operator owns the 3G backhaul infrastructure and the APs are connected to the same backhaul connection. *Table 14* summarizes the WLAN OPEX values.

WiMAX OPEX
The data transmission cost for the backhaul is €5,000 per year; this value was considered as the UMTS backhaul value. The maintenance cost is 5 percent of the total cost of the BS; therefore, it has a cost of €3,872 per year. The site lease on which the BS was mounted has a cost of €13,534 per year. The cost to operate the network is 10 percent of the revenue in year 1, dropping to 7 percent in year 5. Finally, the cost of the general management of the network is 6 percent of the revenue in year 1, dropping to 3 percent in year 5 [18]. *Table 15* shows the WiMAX OPEX values.

IMS OPEX
A value of €50,000 per year is considered to maintain the IMS.

Interconnection Cost
Interconnect charges impact the revenues of the SO according to the fees imposed by the regulatory regimes, the market share of the SO, and the way the operator physically interconnects to other fixed or mobile operators [2]. In this study it was assumed that the 4G operator will not have charges due to interconnection and roaming because there will be a pricing agreement with the other operators.

Results

This section shows the results for the two scenarios considered: Barcelona and La Vera.

TABLE 12
WiMAX CAPEX Values.

CAPEX Item	Cost (€)
WiMAX BS	37,594
Site buildout	37,594
Installation	2,256
Core network and access equipment	375,940
License fee	25,000

TABLE 13
3G OPEX Values.

OPEX Item	Cost (€)
Site lease (urban)	10,000
Site lease (rural)	3,000
Transmission	5,000
Energy consumption	5,100
Operation and maintenance	8,500

TABLE 14
WLAN OPEX Values.

OPEX Item	Cost (€)
Site lease	90
Maintenance	120

TABLE 15
WiMAX OPEX Values.

OPEX item	Cost (€)
Backhaul	5,000
Maintenance	3,872
Site lease	13,534
Operation	10%
General management	6%

Case Study: Urban Area (City of Barcelona)

Barcelona was covered in this scenario. *Table 16* shows the number of BSs that were required to cover the total surface. Due to the large concentration of people in dense urban areas, it was considered that the territory was covered with small radio equipments to satisfy the capacity requirements and offer a good transmission speed. The variations of the surface per technology depend on the percentage that each one covers: UMTS covers 100 percent of the territory, WLAN covers 30 percent of the territory, and WiMAX covers 40 percent of the territory.

The number of BSs required, the core equipment, the cost of the license for UMTS, and the OPEX are the variables that mainly determine the NPV for each scenario. In *Table 17* the outputs for each scenario are presented.

Figure 10 shows the CAPEX values for the operator in each scenario. It can be seen that the costs are higher at the beginning of the deployment, which implies that the network is deployed in the first three years. The value that appears in the seventh year is due to the upgrade capacity of the IMS equipment. In the pessimistic scenario, this cost was unnecessary because the initial capacity of the IMS equipment can support the future increase of mobile users.

Figure 11 presents the OPEX values.

Figures 12 and *13* show the cumulative CAPEX and OPEX values, respectively.

Figure 14 shows the annual cash flows, which gives a detailed description of the revenues and costs presented during the deployment. These cash flows are helpful to better understand the NPV. In the pessimistic scenario, the values are relatively low due to the lower number of subscribers.

Figure 15 shows the cumulative cash flow for the whole period. As is shown in *Figure 15*, the optimistic scenario is

TABLE 16

BSs Required in Barcelona.

Technology	Area Type	Surface (km^2)	Coverage/BS (km^2)	BSs Needed
UMTS	Dense urban	100.69	2.53	40
WLAN	Dense urban	30.207	0.13	241
WiMAX	Dense urban	40.276	1.25	33

TABLE 17

Main Economic Indicators for Barcelona.

Scenario	NPV (€)	IRR (%)	PI	Payback Period (Years)
Optimistic Barcelona	564,294,000	1,033	49.83	1
Normal Barcelona	523,864,000	645	30.29	1
Pessimistic Barcelona	505,218,000	466	22.11	1

FIGURE 10

CAPEX Values in Barcelona.

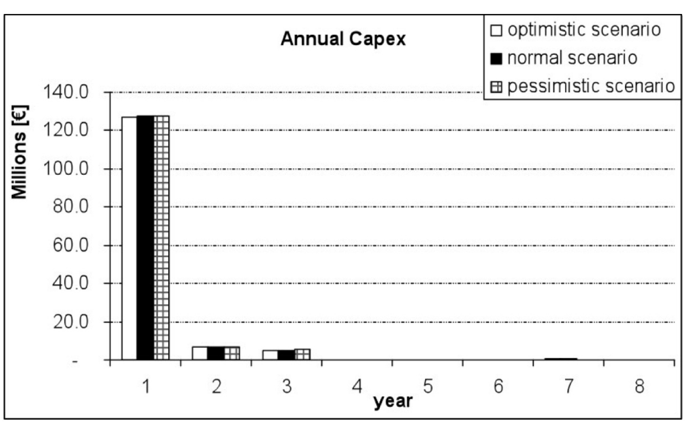


FIGURE 11

OPEX Values in Barcelona.

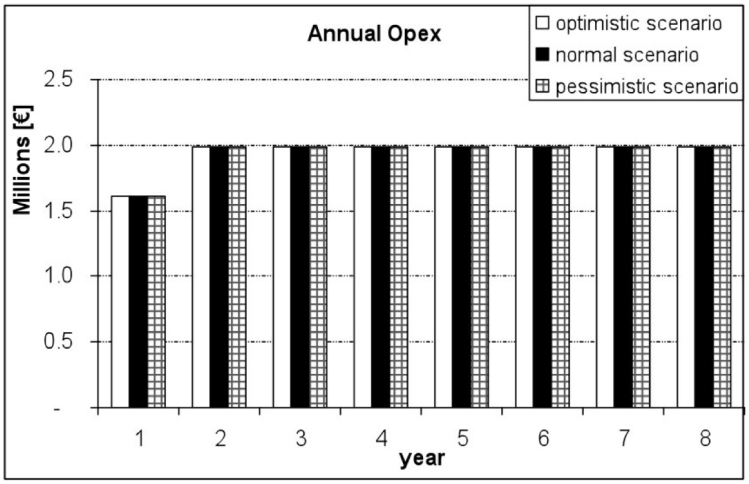


FIGURE 12

Cumulative CAPEX Values in Barcelona.

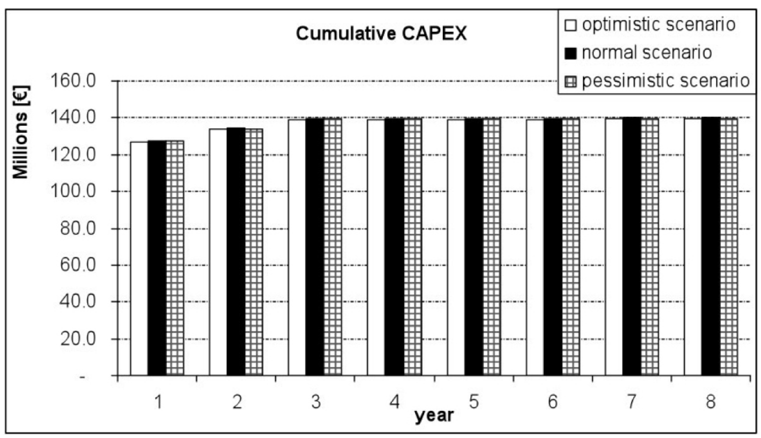
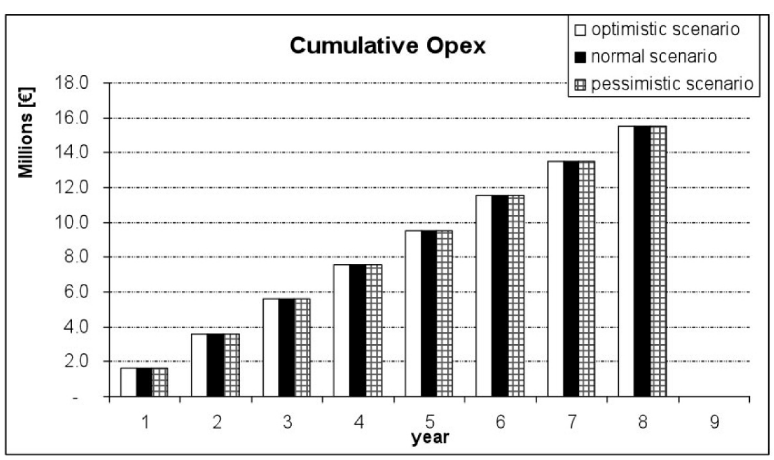


FIGURE 13

Cumulative OPEX Values in Barcelona.



the one with the highest revenues and the pessimistic is the one with the lowest revenues. The main reason for this difference is the number of subscribers.

Case Study: Rural Area (Region of La Vera)

In this scenario, the network will be deployed in the region of La Vera. *Table 18* shows the number of BSs that are required to cover the total surface. This area was covered with larger radio equipments due to low density populations and relatively low demand of services. The variations of the surface per technology depend on the percentage that each one covers: UMTS covers 100 percent of the territory, WLAN covers 15 percent of the territory, and WiMAX covers 50 percent of the territory.

Table 19 presents the main economic indicators for each scenario.

To determine the IRR, the cash flows must turn positive. In the following figures it can be seen that in the timeframe considered for the study, the cash flows do not cross the zero value. On the other hand, the payback period could not be determined exactly for the same reason, although it can be mentioned that it takes more than eight years to recover the

FIGURE 14

Annual Cash Flows in Barcelona.

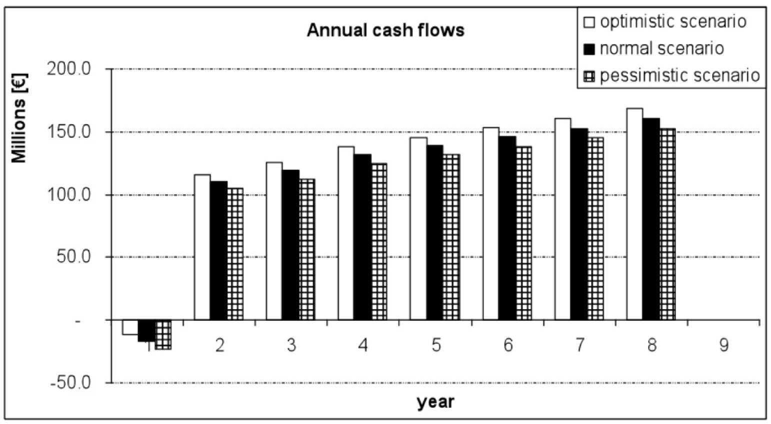


FIGURE 15

Cumulative Cash Flows in Barcelona.

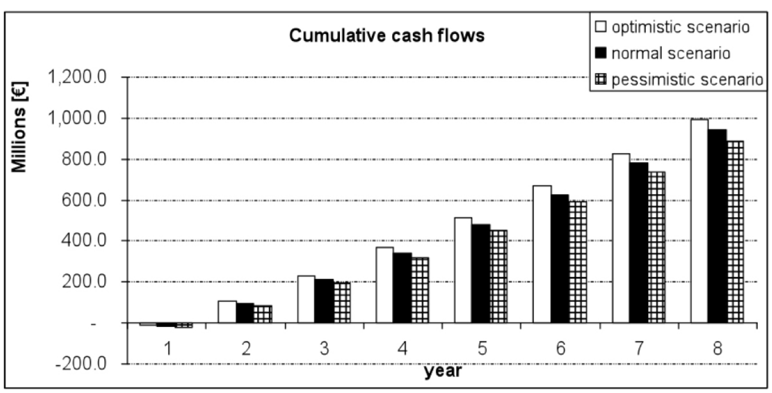


TABLE 18

BSs Needed to Cover La Vera.

Technology	Area type	Surface (km^2)	Coverage/BS (km^2)	BSs needed
UMTS	Suburban/rural	1023.5	34.73	30
WLAN	Suburban/rural	153.5	0.13	1,222
WiMAX	Suburban/rural	512	70.2	8

TABLE 19

Main Economic Indicators for La Vera.

Scenario	NPV (€)	IRR (%)	PI	Payback Period
Normal La Vera	-14,377,000	Not defined	-2.104	More than eight years
Pessimistic La Vera	-14,529,000	Not defined	-2.119	More than eight years
Optimistic La Vera	-14,224,000	Not defined	-2.090	More than eight years

investment. All financial indicators show that the project is not feasible.

Figures 15 and *16* illustrate the annual CAPEX and OPEX values, respectively. It should be noted that in *Figure 15* the license fee is paid along the eight years considered in the study in order to do it more feasibly.

On the other hand, the cumulative CAPEX and OPEX values are presented in *Figures 17* and *18*, respectively.

Finally, *Figures 19* and *20* show the annual cash flows and the cumulative cash flows during the period studied. It can be seen in *Figure 20* that in the whole period, the revenues do not cover the running cost of the network or the investment done at the beginning of the study period. Therefore, in this region the project is not feasible.

FIGURE 16

Annual CAPEX Values in La Vera.

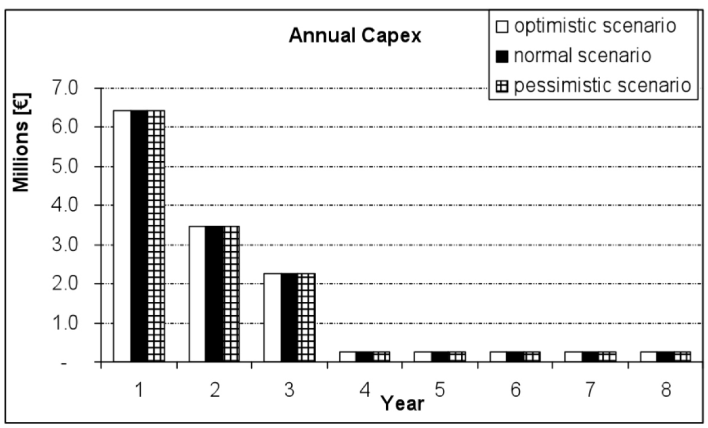


FIGURE 17

Annual OPEX Values in La Vera.

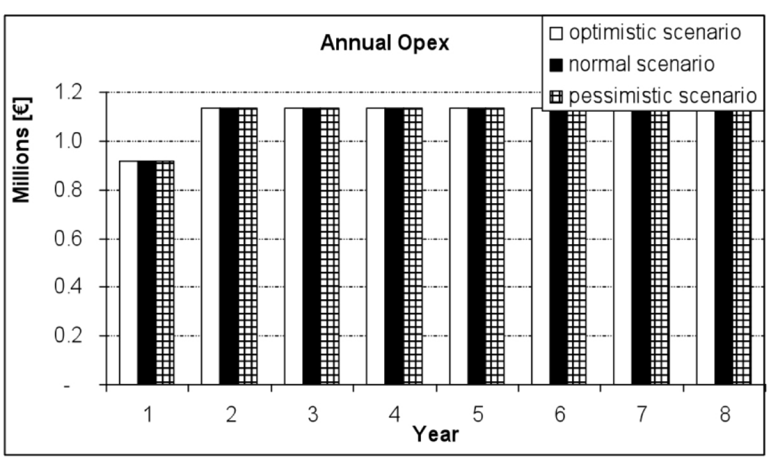


FIGURE 18

Cumulative CAPEX Values in La Vera.

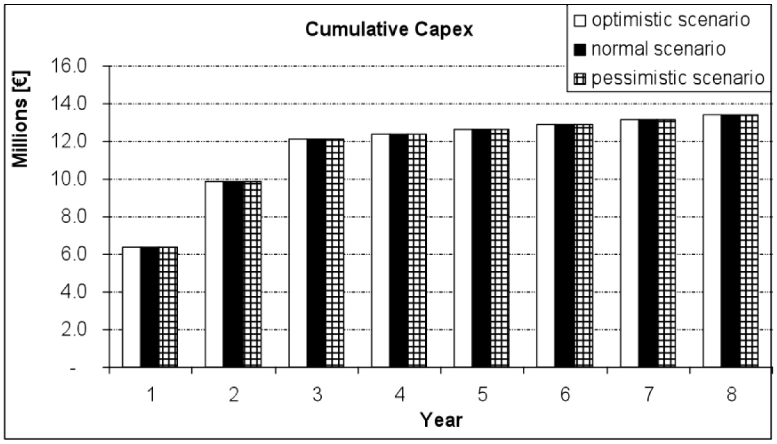


FIGURE 19

Cumulative OPEX Values in La Vera.

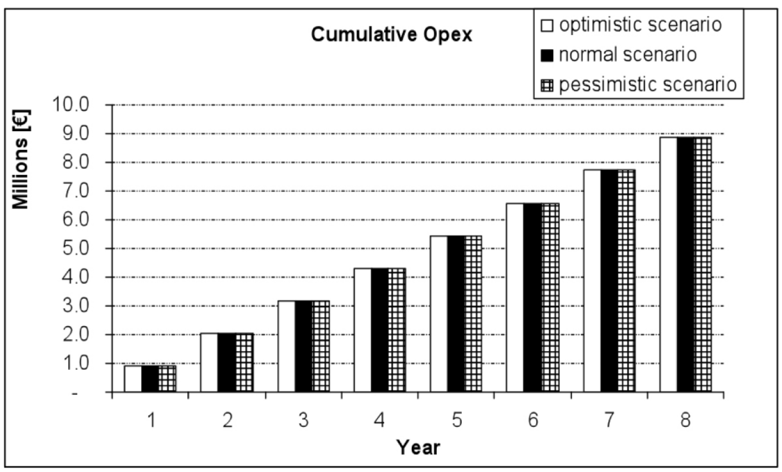


FIGURE 20

Annual Cash Flows in La Vera.

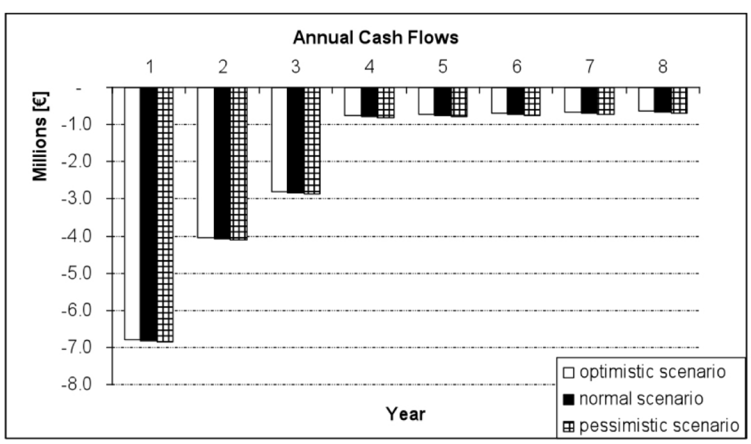
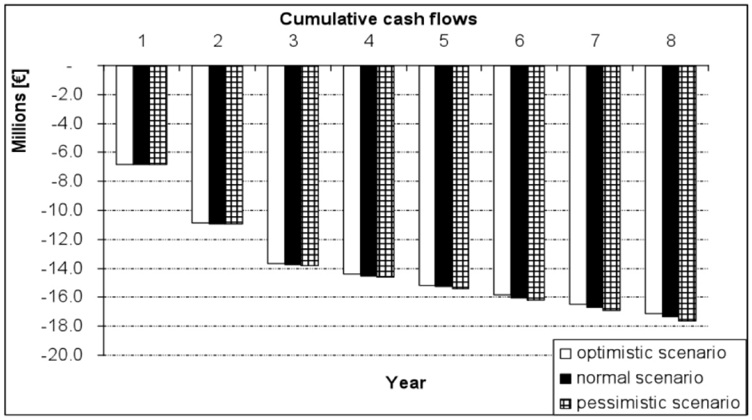


FIGURE 21

Cumulative Cash Flows in La Vera.



Conclusion

A business case for the deployment of a 4G wireless heterogeneous network in Spain was presented. Two regions were considered in the study: the city of Barcelona, a dense urban area, and the region of La Vera, a rural area. Even though there are many parameters that are considered at the moment of building a complex business case, the business case presented in this study takes into account only the main parameters to obtain a trend of the possible consequences of deploying a 4G network.

The results indicate that it is feasible to deploy a heterogeneous network in Barcelona due to the possible number of subscribers. On the other hand, if the 4G heterogeneous network had to be deployed exclusively in a rural area, the project would not be financially feasible.

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Notes

1. This article was written while the author was working at the Pompeu Fabra University in Spain; it represents the personal opinion of the author, and does not necessarily reflect the opinion of WIK-Consult.